# REPORT OF COOPERATIVE RESEARCH ON INSECT CONTROL IN FARM STORED GRAIN

No. 15. Period--January 1 to March 31, 1945

Compiled by R. T. Cotton, Entomologist
Cereal and Forage Insect Investigations
Bureau of Entomology and Plant Quarantine
U. S. Department of Agriculture
Manhattan, Kansas

The material in this report consists largely of unpublished data ~~and should be kept confidential~~. It is made available in its present form for the convenience of the various State and Federal Agencies concerned with the preservation of stored grain from insect damage.

# WHEAT STORAGE

## Observations on Insect Populations in Bins of Wheat as Influenced by Different Systems of Management*

Studies of the fluctuations in the insect populations of wheat stored in Ever-normal granary type bins have been continued. The insect population of the bins were determined by taking five probe samples from the upper southwest quadrant. Forty-one bins of the Management Series were sampled and the number of insects of each species present was determined from the examination of the samples. A summary of the data obtained during the past year is given in table 1. The lesser grain borer (Rhyzopertha dominica F.) and the rice weevil (Sitophilus oryza L.) are classed as "weevils" in the table and all other species are combined as "bran bugs". The flat grain beetle (Laemophloeus minutus Oliv.), the saw-toothed grain beetle (Oryzaephilus surinamensis L.), and the long-headed flour beetle (Latheticus oryzae Waterh.) were the principal bran bugs taken in the samples. The rice weevil was rarely taken.

From table 1 it may be noted that the surviving insect population on March 31, 1945, was generally higher than on the comparable date (April 1) in 1944. This is due in part to the mild winter experienced in this region.

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* Reported by H. H. Walkden and R. B. Schwitzgebel, U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine in cooperation with the Bureau of Plant Industry, Soils and Engineering.

Table 1:--Summary of the insect populations in the upper southwest quadrant of steel and wood bins, Hutchinson, Kansas, 1944-1945.

| Grain Storage Practice | 1944 Apr. 1 | July 1 | Aug. 1 | Sept. 1 | Oct. 1 | Oct. 15 | Nov. 11 | Dec. 27 | 1945 Feb. 9 | Mar. 31 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Average number of insects per 1000-grams | | | | | | | | | |
| **1000-bushel steel bins** | | | | | | | | | | |
| No treatment: | | | | | | | | | | |
| 9.3% moisture | 0 ! | 0.2 | 0.4 | 1.8 | 1.8 | 2.4 | 0.4 | 0.4 | 0 | 0 |
| | 0 " | 0.6 | 1.8 | 1.8 | 0.8 | 1.2 | 0.6 | 1.0 | 0.4 | 0 |
| 11-11.5% moisture | 0.1 | 0.3 | 6.0 | 43.5 | 28.8 | 12.8 | 10.0 | 5.8 | 1.2 | 0 |
| | 1.6 | 11.4 | 40.8 | 57.2 | 63.2 | 36.4 | 34.2 | 28.2 | 9.4 | 8.4 |
| White walls and roof | 0 | 0 | 0 | 3.6 | 1.2 | 0.4 | 0.6 | 0 | 0 | 0 |
| | 0 | 1.6 | 3.6 | 17.4 | 6.8 | 6.4 | 9.6 | 2.6 | 3.0 | 0.8 |
| Fumigation in September | 0 | 0 | 2.8 | 24.2$_{F}$ | 0.4 | 0.6 | 1.0 | 0.2 | 0.2 | 0 |
| | 0 | 0.2 | 12.6 | 82.8$^{F}$ | 1.2 | 1.8 | 6.2 | 1.4 | 0.4 | 0.4 |
| Fumigation in August and October | 0 | 0 | 2.0$_{F}$ | 0.2 | 0.3 | 0.3$_{F}$ | 0 | 0 | 0 | 0 |
| | 0 | 2.2 | 8.7$^{F}$ | 0.3 | 0.6 | 0.5$^{F}$ | 0.5 | 0.1 | 0.1 | 0.1 |
| Turn, clean, and fumigate in September | 0 | 0 | 4.4 | 8.8$_{TF}$ | 0.4 | 0.4 | 1.2 | 0 | 0 | 0 |
| | 0 | 0 | 6.8 | 19.2$^{TF}$ | 0.4 | 0 | 0 | 0.4 | 0 | 0.4 |
| **2740-bushel steel bins** | | | | | | | | | | |
| No treatment: | | | | | | | | | | |
| White walls and roof | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 |
| | 0.5 | 0.1 | 3.3 | 7.2 | 5.2 | 3.5 | 2.6 | 1.5 | 0.7 | 1.7 |
| Painted white and grouped for shading | 0 | 0 | 0 | 0 | 0.1 | 0.1 | 0.3 | 0 | 0 | 0 |
| | 0.5 | 0.6 | 2.2 | 4.0 | 3.5 | 1.0 | 1.1 | 0.6 | 1.2 | 1.2 |
| Fumigation in September | 0 | 0.1 | 1.0 | 7.5$_{F}$ | 0 | 0.7 | 0.1 | 0.1 | 0 | 0 |
| | 1.8 | 4.6 | 5.8 | 11.8$^{F}$ | 0.8 | 1.7 | 0.4 | 0.4 | 0.4 | 1.3 |
| Fumigation in August and October | 0 | 0 | 1.1$_{F}$ | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 |
| | 0 | 0 | 2.2$^{F}$ | 0 | 0.5 | 0.1$^{F}$ | 0 | 0 | 0 | 0 |
| Turn, clean, and fumigate in September | 0 | 0.5 | 6.3 | 61.4$_{TF}$ | 0.1 | 0 | 0.1 | 0 | 0 | 0 |
| | 3.6 | 13.5 | 87.9 | 80.9$^{TF}$ | 0.2 | 0 | 0.1 | 0.2 | 1.1 | 0.5 |
| **1500-bushel wood bins** | | | | | | | | | | |
| White walls and roofs | 0 | 0 | 0 | 0 | 0.4 | 0 | 0.8 | 0 | 0 | 0 |
| | 0 | 1.0 | 10.4 | 21.2 | 17.4 | 14.6 | 34.4 | 51.2 | 23.6 | 2.4 |
| White walls | 0 | 0 | 0.2 | 0.6 | 4.2 | 2.0 | 1.6 | 1.2 | 0 | 0 |
| | 0 | 1.2 | 7.3 | 47.2 | 22.8 | 25.6 | 8.0 | 9.6 | 2.8 | 0.8 |
| Red walls | 0 | 0.2 | 1.2 | 2.8 | 5.6 | 3.6 | 3.6 | 2.0 | 0 | 0 |
| | 0.4 | 6.8 | 55.0 | 60.4 | 80.2 | 41.4 | 22.0 | 20.4 | 3.6 | 1.2 |

Legend: ! = Weevils: includes lesser grain borer and rice weevil.
" = Bran bugs: all species except the weevils.
F = Grain fumigated.
T = Grain turned and cleaned.

## Studies on the Amount of Insect Damage to Wheat Stored in Farm-type Bins

During the course of the investigation on the insects affecting wheat stored in farm-type bins, the question has frequently been raised as to the amount of damage caused by insects infesting the grain during the storage period. In an effort to obtain information on this point estimates of damage were made in the Management Series bins on the Hutchinson Experimental Wheat Storage Site, and also in farm granaries in the vicinity of Hutchinson. At the Hutchinson site, the samples taken in the population study were used for the determination of damage. Probe samples were taken from the locations as indicated in table 2 and cut to approximately 50 grams each. The samples were weighed on a torsion balance accurate to 0.1 gram. The insect-damaged kernels were then separated, weighed and the percent damage calculated. It may be noted from table 2 that over the period from April, 1943, to February, 1945, the greatest amount of insect damage occurred in untreated steel bins of 11-11.5 per cent moisture. It is of interest to note that in bin ½-2 with white walls and roof, a rather severe infestation of the Indian meal moth developed during the season of 1944, but the amount of damage was not sufficient to cause loss of grade. It is believed that the relatively cool temperatures existing in the space over the grain, induced by the white roof, together with the high moisture content of this wheat (12.3%) created conditions favorable for the increase of the Indian meal moth. The infestation was brought under control before the end of season by parasites.

Bins 3-10 and 3-11 were fumigated when they were filled in July, 1941. Since that time they have been given no further treatment, but have sustained much less damage than was expected. However, insect infestation has imparted a sour odor to portions of the grain and samples have been designated "sample grade" for that reason. Hence, it can be concluded that although the total amount of insect damage may be small, the odor imparted by insects causes severe loss in grade.

Observations were made during March in a limited number of farm granaries to determine surviving insect populations and also the amount of damage caused by insects to grain stored on the farm. This survey was planned for last fall, but automotive difficulty at that time prevented it. During the winter months muddy roads caused further delay, with the result that the trip had to be postponed until March. By that time much of the farm-stored wheat had been removed from the bins, so that only a few farm granaries containing grain were located. The results of this limited survey are given in table 3. The amount of damage was determined as described previously. It may be noted from table 3 that the moisture

in the surface grain was higher than in other portions of the wheat. Similar accumulation of moisture during the winter months in the surface layer has been noted in the wheat stored at the Hutchinson Storage Site. With the advent of warmer weather this moisture is given off.

The insect populations in the bins inspected were generally low, that of the cadelle probably being much lower than is actually the case, since this species enters the wooden bin walls for hibernation and at the time of inspection had not emerged into the grain. The amount of insect damage in the various locations in the bins ranged from 0.1 to 3.9 per cent. This amount of damage had occurred since the wheat was put in storage at harvest early in July, 1944.

In one box-car granary, samples were taken at one-foot levels to determine the extent and location of damage caused by the cadelle. The results are given in table 4, from which it is evident that the greatest damage occurred near the walls in the upper portion of the wheat.

Table 2:--Amount of insect damage occurring in wheat stored in steel and wood bins under different grain storage practices from April 1943 to February 1945, Hutchinson, Kansas.

| Grain storage practice | Bin No. | Amount of insect damage (weight basis) Center % | South % | Southwest % | West % | Surface % | Average % |
|---|---|---|---|---|---|---|---|
| **1000-bushel steel bins** | | | | | | | |
| No treatment: | | | | | | | |
| 9% moist. | 1/2-3 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.1 |
| | 1/2-6 | 0.2 | 0.6 | 0.3 | 0.5 | 0.0 | 0.3 |
| 11-11.5% moisture | | | | | | | |
| | 3-10 | 1.6 | 11.1 | 5.7 | 2.4 | 5.6 | 5.3 |
| | 3-11 | 3.6 | 8.6 | 4.0 | 2.3 | 2.9 | 4.3 |
| White walls and roofs | | | | | | | |
| 12.3% moisture | | | | | | | |
| | 1/2-2 | 1.3 | 3.9 | 7.8 | 4.1 | 10.8 | 5.6 * |
| 11.3% moisture | | | | | | | |
| | 1-3 | 0.3 | 1.0 | 1.7 | 2.2 | 2.2 | 1.5 |
| Fumigation in September | | | | | | | |
| | 3-13 | 0.0 | 0.5 | 1.0 | 1.2 | 1.0 | 0.7 |
| | 4-12 | 2.5 | 0.9 | 2.7 | 1.0 | 0.6 | 1.5 |
| Fumigation in August and October | | | | | | | |
| | 1/2-5 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 |
| | 4-5 | 0.2 | 0.1 | 0.1 | 0.4 | 0.0 | 0.2 |
| | 2-12 | 0.4 | 0.6 | 0.4 | 0.8 | 0.3 | 0.5 |
| | 3-12 | 0.8 | 0.5 | 0.5 | 1.0 | 0.9 | 0.7 |
| Turn, clean and fumigate in September | | | | | | | |
| | 3-14 | 0.2 | 0.0 | 0.5 | 0.5 | 0.9 | 0.4 |
| **1500-bushel wood bins** | | | | | | | |
| White walls and roof | | | | | | | |
| | 13-9 | 0.4 | 0.0 | 0.6 | 0.2 | 0.7 | 0.4 |
| White walls | 13-11 | 1.1 | 1.4 | 0.5 | 0.1 | 0.1 | 0.6 |
| Red walls | 13-10 | 1.0 | 0.5 | 2.5 | 1.3 | 1.5 | 1.4 |

* Damage in two white bins caused by Indian meal moth infestation of surface grain. In all other bins the lesser grain borer caused the major portion of the damage.

Table 3:--Insect populations, moisture content and amount of insect damage in wheat stored in wood granaries on farms near Hutchinson, Kansas, March 1945.

| Cooperator | Type of bin | Location of sample | Moisture content % | No. insects per 1000-gram sample Cadelle | Branbugs | Insect damage % |
|---|---|---|---|---|---|---|
| G. Dyck | Boxcar | Center | 11.5 | | 0 | 3.9 |
| | | Center surface | 12.2 | | 0 | 3.9 |
| | | West | 11.2 | | 0 | 1.8 |
| | | West surface | 12.8 | | 0 | 2.1 |
| D. Trostle | Wood granary covered with sheet metal | Center | 10.5 | | 0 | 0.2 |
| | | Center surface | 12.4 | | 0 | 2.3 |
| | | South | 10.4 | | 2 | 0.1 |
| | | South surface | 11.5 | | 6 | 0.9 |
| C. Trostle | Wood granary | Center | 12.3 | 2 | 2 | 0.2 |
| | | Center surface | 12.8 | | 0 | 0.1 |
| | | West | 11.8 | | 0 | 0.2 |
| | | West surface | 13.6 | | 12 | 0.2 |
| W. Peirce | Boxcar | Center | 11.7 | | 4 | 0.9 |
| | | Center surface | 13.1 | | 0 | 0.7 |
| | | South | 11.3 | | 0 | 0.9 |
| | | South surface | 11.8 | | 4 | 1.4 |
| C. Shardien | Boxcar | Center | 12.5 | | 10 | 1.6 |
| | | Center surface | 12.8 | | 8 | 0.6 |
| | | West | 12.1 | | 6 | 0.5 |
| | | West surface | 13.2 | | 16 | 1.6 |
| R. Snodgrass | Wood granary | Center | 12.5 | | 0 | 0.4 |
| | | Center surface | 13.8 | | 0 | 2.1 |
| | | South | 12.5 | 2 | | 2.4 |
| | | South surface | 13.2 | | 0 | 1.2 |
| E. Swanson | Wood granary (South, east and west walls sprayed with DDT before filling) | Center | 13.6 | | 0 | 0.4 |
| | | South | 13.9 | | 6 | 0.7 |
| | | Center surface | 14.4 | | 4 | 0.2 |
| | | North wall | 13.7 | | 0 | 1.4 |
| | | North surface | 15.0 | 2 | 6 | 0.9 |
| | | South wall | 13.0 | | 0 | 0.2 |
| | | South surface | 14.4 | | 0 | 0.2 |
| | | West wall | 13.3 | | 2 | 0.4 |

Table 4.--Extent and location of damage caused by the cadelle in a lot of 1944 wheat stored in a boxcar granary, Hutchinson, Kansas, March 1945.

| Location of sample distance above floor | No. insects per 1000-gram | | Insect damage | Moisture content |
|---|---|---|---|---|
| | Cadelle | Branbugs | % | % |
| Center | | | | |
| Surface | | 2 | 0.2 | 13.7 |
| 4-5' | | 8 | 0.4 | 13.2 |
| 3-4' | 12 | 3 | 1.8 | 12.4 |
| 2-3' | | 0 | 0.1 | 11.6 |
| 1-2' | | 3 | 0.2 | 11.0 |
| 0-1' | | 0 | 1.1 | 11.1 |
| 1' from south wall | | | | |
| 4-5' | 3 | 3 | 3.3 | 12.6 |
| 3-4' | 6 | | 6.0 | 11.5 |
| 2-3' | 6 | | 4.1 | 11.1 |
| 1-2' | 12 | | 3.1 | 11.2 |
| 0-1' | 3 | | 2.9 | 11.2 |
| 1' from west wall | | | | |
| 4-5' | 9 | | 4.4 | 12.8 |
| 3-4' | 6 | | 5.1 | 12.5 |
| 2-3' | 0 | | 3.6 | 12.0 |
| 1-2' | 6 | | 1.9 | 11.6 |
| 0-1' | 6 | | 1.4 | 11.9 |

## Experimental Fumigation and Dust Treatment of Stored Wheat

Two 2740-bushel steel bins of wheat on the Hutchinson site went into the winter with high insect populations and were purposely left in that condition to determine if low winter temperatures would be sufficient to control the infestation in that size of bin. Early in January these bins were observed to be heating because of insects and shortly thereafter the surface grain became excessively moist and caked in the area over the most intense infestation: in the center of bin 7-10 which had been turned in September 1944, and in the south quadrant of bin 6-2 which had not been disturbed.

By the middle of March it became evident that the heat produced by the insects was too great to be controlled by the winter temperatures, and it was decided to resort to fumigation. The caked and high moisture grain was removed from the affected surface portions and the fumigant applied to the entire surface. The results are given in table 5. The fumigant used was one of several proposed mixtures designed to give adequate kills in all parts of the grain mass. The results of these first tests were excellent, particularly so in view of the heavy infestation present in the wheat.

Table 5:--Number of insects per 1000-gram sample in bins 6-2 and 7-10 before and after fumigation, Hutchinson, Kansas, March 28, 1945. Fumigant: ethylene dibromide, 5%; carbon disulphide, 10%; ethylene dichloride, 25%; carbon tetrachloride, 60%. Dosage: 2 gallons per 1000 bushels.

| Location of sample | Bin 7-10: Living insects per 1000 grams, Number | | | | | | Moisture % | Bin 6-2: Living insects per 1000 grams, Number | | | | | Moisture % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | L | RF | LH | F | S | Total | | L | RF | LH | F | Total | |
| **Before Fumigation** | | | | | | | | | | | | | |
| 11-12 | 24 | 21 | 150 | 3 | 6 | 204 | 11.9 | | | | | | |
| 10-11 | 30 | 60 | 210 | 9 | | 309 | 11.2 | 54 | 60 | 75 | 9 | 198 | 12.3 |
| 9-10 | 6 | 30 | 72 | 3 | 3 | 114 | 9.5 | 30 | 6 | 60 | | 96 | 11.2 |
| 8-9 | 15 | 62 | 45 | 3 | | 125 | 9.1 | 30 | 30 | 60 | 3 | 123 | 10.9 |
| 7-8 | 12 | 58 | 63 | | | 133 | 9.3 | 42 | 30 | 36 | 6 | 114 | 10.6 |
| 6-7 | 12 | 39 | 120 | | | 171 | 9.9 | 66 | 33 | 30 | 15 | 144 | 10.4 |
| 5-6 | 8 | 40 | 104 | 2 | | 154 | 10.2 | 28 | 16 | 12 | 6 | 62 | 10.2 |
| 4-5 | | 15 | 36 | 6 | | 57 | 10.3 | 9 | 9 | 6 | | 24 | 10.1 |
| 3-4 | | | 3 | | | 3 | 10.6 | 12 | 9 | 9 | | 30 | 9.9 |
| 2-3 | | 3 | 3 | | | 6 | 10.8 | 12 | 9 | 6 | | 27 | 9.7 |
| 1-2 | 3 | | | | | 3 | 11.0 | 6 | 12 | 9 | | 27 | 9.4 |
| Floor-1 | 2 | | 2 | | 2 | 6 | 11.1 | 24 | 9 | 81 | | 114 | 10.2 |
| Total | 112 | 328 | 811 | 26 | 11 | 1288 | | 313 | 223 | 384 | 39 | 959 | |
| Average | 9.3 | 27.3 | 67.6 | 2.2 | 0.9 | 107.3 | | 28.5 | 20.3 | 34.9 | 3.6 | 87.2 | |

After fumigation no living insects found.

Legend:

L = Lesser grain borer
LH = Long-headed flour beetle
F = Flat grain beetle
RF = Red flour beetle
S = Saw-toothed grain beetle

## Results with Almicide Dust

About a year ago, a 150-bushel lot of wheat, heavily infested with rice weevils, was treated with Almicide dust. Samples taken shortly after treatment showed that practically all of the insects were dead. The wheat was left in the bin during the 1944 season to ascertain if any infestation would develop. Samples of both the treated wheat, and the untreated control were taken on November 11, 1944, and again on March 28, 1945. The results are summarized in table 6. It may be seen that some infestation developed in the treated wheat during the summer and fall but was not as intense as that in the untreated control. Infestation in both lots disappeared during the winter months.

Table 6: -- Insect populations in a 150-bushel lot of wheat treated with Almicide dust March 2, 1944, Hutchinson, Kansas.

| Location and date of sample | Number insects per 1000-gram sample | | | Moisture content (%) |
|---|---|---|---|---|
| | Rice weevil | Lesser grain borer | Bran bugs | |
| November 11, 1944 | | | | |
| Center | 16 | 12 | 0 | 12.2 |
| North | 0 | 1 | 0 | 12.2 |
| South | 9 | 4 | 0 | 12.4 |
| Untreated control | 7 | 124 | 12 | 11.9 |
| March 28, 1945 | | | | |
| Center | No living insects found | | | 12.1 |
| North | do | | | 12.3 |
| South | do | | | 12.5 |
| Untreated control | do | | | 12.5 |

## Effect of Temperature, Moisture, and Dockage on the Survival and Reproduction of the Rust Red Flour Beetle*

In this series of tests conducted at a constant temperature of 80° F., the same general procedure as that used in previous tests was followed. Twenty newly formed adults (10♀ and 10♂), were confined in 9, 12, and 15% moisture wheat with varying amounts of dockage ranging from clean wheat to wheat with 8% dockage. Weekly examinations of the various cultures to determine the percentage of survival and the number of progeny produced were made. The results of these examinations covering a period of 5 weeks are summarized in table 7. Except in clean wheat in the 9% moisture series, a very high percentage of survival is noted. This series has, of course, not been in operation for a long enough period to permit great variations in the percentage of survival. Adults of this species are able to survive under extremely dry conditions, and may survive many weeks on very dry food.

As was found true in other tests with this insect, dockage, especially in dry wheat, enhances the survival of the adults.

At the end of 5 weeks, pupae were recovered only in the 8% dockage lots of the 12% moisture series, and in the 2, 4, and 8% dockage lots of the 15% series. No pupae were recovered prior to the end of the 5th week.

In another series of tests conducted at a constant temperature of 55° F. over a period of eight weeks, we find that the percentage of survival increases as the moisture content of the wheat is increased. It will be noted from table 8 that there is practically no difference in the percentage of survival, within a given moisture level, in cultures containing varying amounts of dockage. It is evident that at 55° F. the adult insects do not survive for long periods of time. The increased survival due to increased moisture, is in keeping with all of our previous observations. These tests were discontinued after 8 weeks, due to a breakdown of the equipment. Since there was only a small survival in practically all lots of the 15% moisture series at this time, it is doubtful whether any adults would have survived for any extended length of time.

No reproduction was observed in any of the colonies held at 55° F. It is doubtful if any oviposition occurs at this temperature.

To determine whether the eggs of the rust red flour beetle would hatch at a temperature as low as 55° F., four lots of 50 eggs each were confined in shell vials at this temperature. One lot was removed at the end of two weeks and another at the end of one month. None of the eggs had hatched. These were then placed in an incubator at 80° F. Five eggs, of the lot removed from the 55° F. constant temperature chamber after two weeks, hatched within seven days after they had been placed at a constant temperature of 80° F. No eggs hatched from the lot which had been held at 55° F. for one month. No eggs have hatched from the remaining two lots which have been in the 55° F. chamber for 3 months. Of two lots of 50 eggs each held at 80° F. constant temperature, 34 and 33 larvae hatched on the 6th and 7th day. These observations indicate that even if any oviposition occurred at 55° F., no hatching of the eggs would take place if the eggs were confined at this temperature for periods of two weeks or more.

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* - Reported by R. T. Cotton and J. C. Frankenfeld.

Table 7: -- Percentage of survival of rust red flour beetle in 9, 12, and 15% moisture wheat with varying amounts of dockage at 80° F.

| Moisture content of wheat and food media | Percentage of survival after | | | | | Number of pupae after 5 weeks |
|---|---|---|---|---|---|---|
| | 1 Week | 2 Weeks | 3 Weeks | 4 Weeks | 5 Weeks | |
| 9% Wheat | | | | | | |
| Clean wheat | 100 | 100 | 75 | 50 | 25 | 0 |
| Same plus 0.5% dockage | 95 | 95 | 95 | 90 | 90 | 0 |
| Same plus 1.0% dockage | 100 | 100 | 100 | 100 | 100 | 0 |
| Same plus 2.0% dockage | 100 | 100 | 100 | 100 | 100 | 0 |
| Same plus 4.0% dockage | 100 | 100 | 100 | 95 | 95 | 0 |
| Same plus 8.0% dockage | 95 | 90 | 85 | 85 | 85 | 0 |
| 12% Wheat | | | | | | |
| Clean wheat | 100 | 100 | 100 | 95 | 95 | 0 |
| Same plus 0.5% dockage | 100 | 100 | 100 | 100 | 100 | 0 |
| Same plus 1.0% dockage | 100 | 100 | 100 | 100 | 100 | 0 |
| Same plus 2.0% dockage | 100 | 100 | 100 | 100 | 100 | 0 |
| Same plus 4.0% dockage | 100 | 95 | 95 | 95 | 95 | 0 |
| Same plus 8.0% dockage | 100 | 100 | 100 | 100 | 100 | 3 |
| 15% Wheat | | | | | | |
| Clean wheat | 100 | 100 | 100 | 100 | 100 | 0 |
| Same plus 0.5% dockage | 100 | 100 | 100 | 100 | 100 | 0 |
| Same plus 1.0% dockage | 100 | 100 | 100 | 100 | 100 | 0 |
| Same plus 2.0% dockage | 100 | 100 | 100 | 100 | 100 | 10 |
| Same plus 4.0% dockage | 100 | 100 | 100 | 100 | 100 | 4 |
| Same plus 8.0% dockage | 95 | 95 | 95 | 95 | 95 | 44 |

Table 8: -- Percentage of survival of rust red flour beetle in 9, 12, and 15% wheat with varying amounts of dockage at 55° F.

| Moisture content of wheat and food media | Percentage of survival after | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 Week | 2 Weeks | 3 Weeks | 4 Weeks | 5 Weeks | 6 Weeks | 7 Weeks | 8 Weeks |
| 9% Wheat | | | | | | | | |
| Clean wheat | 95 | 95 | 60 | 30 | 0 | | | |
| Same plus 0.5% dockage | 100 | 95 | 65 | 15 | 0 | | | |
| Same plus 1.0% dockage | 95 | 90 | 70 | 0 | 0 | | | |
| Same plus 2.0% dockage | 100 | 95 | 85 | 45 | 20 | 5 | 0 | |
| Same plus 4.0% dockage | 100 | 95 | 90 | 40 | 20 | 0 | | |
| Same plus 8.0% dockage | 100 | 100 | 80 | 35 | 15 | 0 | | |
| 12% Wheat | | | | | | | | |
| Clean wheat | 100 | 100 | 95 | 75 | 40 | 10 | 0 | |
| Same plus 0.5% dockage | 90 | 90 | 75 | 70 | 40 | 25 | 0 | |
| Same plus 1.0% dockage | 95 | 95 | 85 | 70 | 30 | 15 | 0 | |
| Same plus 2.0% dockage | 100 | 100 | 90 | 60 | 35 | 10 | 0 | |
| Same plus 4.0% dockage | 95 | 95 | 80 | 60 | 40 | 15 | 0 | |
| Same plus 8.0% dockage | 100 | 100 | 85 | 65 | 55 | 25 | 0 | |
| 15% Wheat | | | | | | | | |
| Clean wheat | 100 | 90 | 85 | 75 | 75 | 70 | 70 | 65 |
| Same plus 0.5% dockage | 100 | 100 | 95 | 95 | 80 | 55 | 30 | 10 |
| Same plus 1.0% dockage | 100 | 95 | 95 | 75 | 55 | 30 | 20 | 10 |
| Same plus 2.0% dockage | 100 | 100 | 100 | 90 | 60 | 50 | 35 | 20 |
| Same plus 4.0% dockage | 95 | 95 | 90 | 75 | 70 | 65 | 40 | 20 |
| Same plus 8.0% dockage | 100 | 100 | 90 | 80 | 65 | 40 | 10 | 0 |

## Effect of Temperature and Moisture on the Survival and Reproduction of the Granary and Rice Weevils*

Continuing our tests with the effect of temperature and moisture on the granary and rice weevils, a series of tests were conducted at a constant temperature of 55° F. Since, in a previous series run at a constant temperature of 60° F., it was found that a high percentage of survival and considerable reproduction occurred, it seemed advisable to continue our studies and determine at what temperature reproduction would cease. This series of tests has been in operation for 17 weeks and the percentages of survival at bi-weekly intervals are summarized in table 9.

In the 9% moisture series, all adult granary weevils were dead at the end of 9 weeks; and all adult rice weevils at the end of 3 weeks. At the end of 17 weeks, a small percentage of granary weevils survived in the 10% wheat, but all rice weevils were dead at the end of 9 weeks. In the 11, 12, 13, and 14% moisture wheats the percentage of survival increases with the increased moisture content of the wheat.

A very small amount of reproduction by the granary weevil was obtained in the 14% moisture wheat. Since the eggs were laid during the first week that the adults were confined to the 55° F. temperature, and since no subsequent reproduction has occurred, it is doubtful whether the granary weevil will ordinarily oviposit at this temperature.

No reproduction of the rice weevil was obtained, although frequent mating was observed, particularly in the higher moisture wheat cultures.

To determine whether the immature stages would develop at 55° F., wheat containing the egg stage of both the granary and rice weevil, was confined at this temperature, at the start of the above series of of tests. At the end of 17 weeks no emergence of adults from the wheat has occurred.

In another series of tests conducted at 75° F., only 9, 10, and 11% moisture wheat was used. Tests at this temperature for the higher moisture wheat had been completed at an earlier date.

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* - Reported by R. T. Cotton and J. C. Frankenfeld.

This series has been in progress for 9 weeks and the biweekly record of survival is summarized in table 10. As in previous tests the percentage of survival increases as the moisture content of the wheat is increased. In 9% wheat both the granary and rice weevil adults die rather rapidly, so that at the end of 7 weeks all granary weevils were dead. All rice weevils were dead at the end of the 3rd week. In the 10% moisture series an average of 17.5% survival of the granary weevil still persists after 9 weeks, while all rice weevil were dead after 7 weeks. In 11% moisture wheat an average of 42.5% and 19.5% survived after 9 weeks in the case of the granary and rice weevils respectively.

The number of progeny recovered after 9 weeks is listed in the last column of table 10. No reproduction of the rice weevil was obtained in the 9% moisture wheat, which was to be expected since all adults died by the end of the 3rd week. The effect of moisture on reproduction is striking in the case of the 10 and 11% wheat, increasing as the moisture content of the wheat is increased. These records are, of course, not complete, as reproduction records herewith recorded are only from samples of wheat infested during the first 3 weeks of the duration of the series.

Table 10: -- Percentage of survival of granary and rice weevil at 55° F. in wheat of various moisture content.

| Moisture content of wheat and insect used | Percentage of survival after 1 Week | 3 Weeks | 5 Weeks | 7 Weeks | 9 Weeks | 11 Weeks | 13 Weeks | 15 Weeks | 17 Weeks |
|---|---|---|---|---|---|---|---|---|---|
| 9% Wheat | | | | | | | | | |
| Granary weevil | 74 | 32 | 16 | 0 | | | | | |
| do | 74 | 28 | 16 | 8 | 0 | | | | |
| Rice weevil | 50 | 0 | | | | | | | |
| do | 52 | 0 | | | | | | | |
| 10% Wheat | | | | | | | | | |
| Granary weevil | 90 | 58 | 44 | 30 | 28 | 21 | 14 | 10 | 10 |
| do | 92 | 62 | 52 | 44 | 38 | 29 | 20 | 14 | 12 |
| Rice weevil | 62 | 12 | 6 | 0 | | | | | |
| do | 62 | 16 | 10 | 6 | 6 | 0 | | | |
| 11% Wheat | | | | | | | | | |
| Granary weevil | 88 | 86 | 72 | 58 | 50 | 47 | 44 | 34 | 30 |
| do | 92 | 66 | 66 | 60 | 56 | 48 | 40 | 30 | 22 |
| Rice weevil | 74 | 46 | 34 | 34 | 30 | 22 | 14 | 2 | 0 |
| do | 80 | 48 | 30 | 26 | 24 | 17 | 10 | 4 | 0 |
| 12% Wheat | | | | | | | | | |
| Granary weevil | 98 | 80 | 78 | 64 | 50 | 40 | 30 | 28 | 22 |
| do | 90 | 78 | 68 | 62 | 58 | 46 | 34 | 34 | 28 |
| Rice weevil | 82 | 68 | 62 | 58 | 50 | 37 | 24 | 20 | 12 |
| do | 92 | 72 | 60 | 50 | 48 | 38 | 28 | 12 | 8 |
| 13% Wheat | | | | | | | | | |
| Granary weevil | 90 | 86 | 82 | 82 | 76 | 70 | 64 | 64 | 64 |
| do | 100 | 98 | 98 | 90 | 86 | 75 | 64 | 60 | 54 |
| Rice weevil | 96 | 76 | 72 | 72 | 64 | 56 | 48 | 48 | 46 |
| do | 100 | 86 | 76 | 74 | 72 | 68 | 64 | 54 | 50 |
| 14% Wheat | | | | | | | | | |
| Granary weevil | 100 | 100 | 98 | 96 | 92 | 90 | 88 | 88 | 84 |
| do | 100 | 98 | 96 | 94 | 90 | 89 | 88 | 84 | 76 |
| Rice weevil | 94 | 86 | 78 | 66 | 66 | 66 | 66 | 64 | 62 |
| do | 98 | 76 | 76 | 68 | 68 | 65 | 62 | 62 | 54 |

Table 10: -- Percentage of survival of granary and rice weevils at 75° F. in wheat of 9, 10, and 11% moisture content.

| Moisture content of wheat and insect used | Percentage of survival after | | | | | Number of progeny after 9 weeks |
|---|---|---|---|---|---|---|
| | 1 Week | 3 Weeks | 5 Weeks | 7 Weeks | 9 Weeks | |
| 9% Wheat | | | | | | |
| Granary weevil | 100 | 14 | 8 | 2 | 0 | 0 |
| do | 98 | 8 | 6 | 1 | 0 | 2 |
| Rice weevil | 98 | 0 | | | | |
| do | 75 | 0 | | | | |
| 10% Wheat | | | | | | |
| Granary weevil | 98 | 62 | 27 | 21 | 19 | 43 |
| do | 100 | 50 | 24 | 19 | 16 | 19 |
| Rice weevil | 95 | 6 | 4 | 1 | 0 | 1 |
| do | 97 | 48 | 1 | 0 | | 3 |
| 11% Wheat | | | | | | |
| Granary weevil | 100 | 80 | 67 | 64 | 62 | 160 |
| do | 95 | 23 | 23 | 23 | 23 | 31 |
| Rice weevil | 100 | 27 | 21 | 18 | 17 | 125 |
| do | 100 | 79 | 31 | 26 | 22 | 142 |